A LABORATORY STUDY OF SUBJECTIVE ANNOYANCE RESPONSE TO SONIC BOOMS AND AIRCRAFT FLYOVERS

By

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Three experiments were conducted to determine subjective equivalence of aircraft subsonic flyover noise and sonic booms. Two of the experiments were conducted in a loudspeaker-driven sonic boom simulator, and the third in a large room containing conventional loudspeakers. The sound generation system of the boom simulator had a frequency response extending to very low frequencies (about 1 Hz) whereas the large room loudspeakers were limited to about 20 Hz. Subjective equivalence between booms and flyovers was quantified in terms of the difference between the noise level of a boom and that of a flyover when the two were judged equally annoying. Noise levels were quantified in terms of the following noise descriptors: Perceived Level (PL), Perceived Noise Level (PNL), C-weighted sound exposure level (SELC), and A-weighted sound exposure level (SELA). Results from the present study were compared, where possible, to similar results obtained in other studies. Results showed that noise level differences depended upon the descriptor used, specific boom and aircraft noise events being compared and, except for the PNL descriptor, varied between the simulator and large room. Comparison of noise level differences obtained in the present study with those of other studies indicated good agreement across studies only for the PNL and SELA descriptors. Comparison of the present results with assessments of

community response to high-energy impulsive sounds made by Working Group 84 of the National Research Council's Committee on Hearing, Bioacoustics, and Biomechanics (CHABA) showed good agreement when boom/flyover noise level differences were based on SELA. However, noise level differences obtained by CHABA using SELA for aircraft flyovers and SELC for booms were not in agreement with results obtained in the present study.

INTRODUCTION

NASA Langley Research Center has conducted a series of laboratory studies (references 1-7) to quantify subjective loudness and annoyance response to simulated sonic booms. These studies, conducted in the Langley Sonic Boom Simulator, were performed in support of the NASA High Speed Research Program. Results were used to: quantify the effects of boom shaping (minimization) on subjective loudness of outdoor booms (refs. 1,2), establish the validity of magnitude estimation scaling for assessing sonic boom subjective effects (ref. 3), determine effects of boom waveform asymmetry on loudness (ref. 4), define loudness and annoyance response to simulated outdoor and indoor booms (ref. 5), investigate loudness of sonic booms with ground reflections (ref. 6), and quantify loudness of a wide range of ground-measured sonic boom signatures obtained from actual aircraft in flight (ref. 7). In addition, all of these studies evaluated several descriptors as estimators of sonic boom loudness and/or annoyance. None of the NASA studies, however, addressed the question of how subjective response to sonic booms relates to subjective response to aircraft flyover events. This is an important issue since establishment of boom/flyover relationships may permit available information on acceptability of aircraft noise exposure to be applied to sonic booms.

An early review (ref. 8) of laboratory studies of sonic boom effects on people indicated that Perceived Noise Level (PNL) of a sonic boom as heard outdoors may exceed the PNL of the flyover sound of a subsonic jet by about 12 dB when the two are judged to be equally annoying. Since this result was based on limited data, it was noted that more data were required before the results could be generalized. Another laboratory study (ref. 9) quantified the effect of rise time upon perceived noisiness of booms heard indoors and judged relative to a standard reference noise from a subsonic jet aircraft. Boom/flyover noise equality was established for a large number of physical measures of maximum and effective perceived noise level. For PNL the indoor boom levels exceeded the indoor flyover levels by about 4 dB as compared to the difference of 12 dB noted in reference 8 for outdoor booms and flyovers. This indicates that annoyance differences between booms and flyovers were reduced when the two were heard indoors. A possible reason could be rattle and window/wall vibration due to transmission of the low frequency boom components through the walls.

Subjective equivalence of sonic booms and subsonic aircraft flyover noise, using recordings of each type of sound, was investigated in a sonic boom simulator (ref. 10) and a small room (ref. 11). In these studies subjective equivalence was determined in terms of PNL for the aircraft flyovers and peak overpressure for the booms. Results of the two studies agreed well with one another although the use of peak overpressure to characterize the booms is questionable. Peak overpressure has been shown to be a poor estimator of subjective response (see refs 1-5) and cannot easily be related to community response descriptors developed for subsonic aircraft noise. It would be better to compare sonic booms and subsonic aircraft noise on the basis of common descriptors and then use data on community response to aircraft noise to infer sonic boom acceptability.

Working Group 84 of the National Research Council's Committee on Hearing, Bioacoustics, and Biomechanics (CHABA) performed an assessment and re-analysis of available sonic boom data as of 1981. Their effort resulted in a comprehensive set of procedures for specifying the physical descriptions of impulsive noise and in methods for assessing the impact of this noise upon people (reference 12). CHABA first considered whether A-weighted sound exposure level was a satisfactory means for assessing human response to sonic booms. Based upon their analysis of available data it was concluded that A-weighted sound exposure level of sonic booms must be 11 to 15 dB lower than A-weighted sound exposure level of subsonic airplane noise when judged equally annoying, and that the size of this offset depended upon the characteristics of the particular noise events being compared. CHABA therefore recommended that community response to impulsive and non-impulsive noise not be compared in terms of SELA. Instead, it was proposed that the two types of sound be compared in terms of SELC for booms and SELA for flyovers. Reasons included: (a) different impulsive sources have different SELA's that equate to the same annoyance as that due to subsonic airplane noise; (b) contributions of booms to overall day-night average A-weighted sound level would be completely masked by other noise sources except for all but the highest sonic boom exposures; and (c) available data in terms of SELC for booms and SELA for flyovers that corresponded to equal annoyance collapsed into a single linear function. Based upon this function CHABA observed that SELC for booms was about 5 dB less than SELA for aircraft noise when judged equally annoying.

The purpose of this paper is to present the results of three experiments recently conducted at NASA Langley Research Center to determine annoyance equivalence of sonic booms and aircraft flyovers and to compare the equivalence results to those of prior studies where possible. The first two experiments were conducted in the Langley Sonic Boom Simulator (a relatively reflection-free environment) and the third experiment in the Langley Exterior Effects Room, an acoustically-treated lecture room. The first experiment used an 11-point continuous numerical scale to obtain subjective reactions from which points of subjective equality between the booms and flyovers could be determined. The second experiment replicated the first experiment except that the method of paired comparison (described later) was used. It was conducted to validate the subjective equality points obtained in the first experiment. The third experiment used the 11-point continuous numerical scale scale to determine the extent to which subjective equality points obtained in a reverberant environment differed from those obtained in the quasi-anechoic environment of the sonic boom simulator.

EXPERIMENTAL METHOD

Sonic Boom Simulator

Experiments 1 and 2 were conducted in the Langley Research Center's Sonic Boom Simulator. This simulator provided a relatively reflection-free environment and close control of the test stimuli. In particular, the boom simulator could reproduce the very low frequencies (down to about 1 Hz) of the sonic boom spectra. Construction details, performance capabilities, and operating procedures of the simulator are given in reference 1. The simulator, shown in figure 1, is a person-rated, airtight, loudspeaker-driven booth capable of accurately reproducing user-specified sonic boom waveforms at sound pressure levels up to approximately 138 dB. Input waveforms are "preprocessed" to compensate for nonuniformities in the frequency and phase response characteristics of the simulator booth and sound reproduction system.

Exterior Effects Room

Experiment 3 was conducted in the Langley Research Center's Exterior Effects Room (EER). This room, shown in figure 2, was designed to acoustically simulate the outdoor environment in the airport community. The room has approximate dimensions of 4.2m X 8.5m X 9m ($320m^3$), a reverberation time of approximately 0.25 sec at 1000 Hz, and a seating capacity of 39, although, typically, only four to six subjects are tested at a time. Four large floor speakers were arranged across the front of the room as shown in figure 2. A photograph of the seating arrangement showing two test subjects is presented in figure 3.

Test Subjects

Thirty-two test subjects were used in each experiment for a total of 96 subjects (40 male, 56 female). The subjects were obtained from a subject pool of local residents. Ages of the test subjects ranged from 18 to 67 years with a median age of 35 years. All subjects were required to undergo audiometric screening prior to the tests in order to verify normal hearing.

Experimental Design

Test Stimuli

The basic test stimuli used as input to the sound generation systems for each experiment consisted of two recorded aircraft flyovers and two simulated outdoor sonic booms. The two aircraft flyovers were recordings of a B747 and an A300 made during approach. The two booms were symmetrical N-waves, one with a rise time of 1 millisecond (designated N1) and the other with a rise time of 3 milliseconds (designated N3). The sonic booms were computer-generated and "pre-processed" prior to playback in the boom simulator. They were not "pre-processed", but were high-pass filtered (to match the frequency response of the speakers), prior to playback in the EER. The flyover recordings were played directly from the tape recorder to each test facility without modification.

Scaling Methods

Experiments 1 and 3 used a continuous 11-point numerical scale to obtain subjective annoyance reactions. The scale was labeled at the low end (scale value of 0) by the words "NOT ANNOYING AT ALL" and at the high end (with a scale value of 10) by the words "EXTREMELY ANNOYING". The scale, and instructions given to the subjects explaining how to use the scale, are given in Appendix A.

Experiment 2 used the psychometric method of paired comparisons. This method involved presentation of the test stimuli in pairs with one member of the pair being a sonic boom and the other member a flyover. Upon listening to a stimulus pair, a subject was asked to indicate which of the pair was most annoying. The paired comparison instructions are given in Appendix B. Using this method, the points of subjective equality between each unique flyover/boom pair could be determined. For example, suppose it was desired to find the level of a sonic boom (in terms of an appropriate noise descriptor) that was equal to the annoyance produced by a fixed level of a flyover. This was determined by pairing the flyover with varying levels of the sonic boom and asking subjects to tell which member of each pair was most annoying. The level of the sonic boom at which fifty percent of the subjects rated it more annoying was defined as the point of subjective equality.

Description of Experiments

Experiments 1 and 3.- The two booms and two flyovers described earlier were each presented at five levels, for a total of 20 stimulus presentations. These were randomly assigned to two sessions containing 10 stimuli each. To reduce effects of order, the booms within each session were presented in reverse sequence to one-half of the test subjects.

Experiment 1 was conducted in the sonic boom simulator and experiment 3 in the EER. The low frequency cutoff of the floor speakers (about 20 Hz) and the high-pass filtering of the speaker inputs prevented reproduction of the intense low frequency components of the booms in the EER.

Experiment 2.- The test stimuli for experiment 2 were presented in pairs defined by four stimulus pair groupings. A stimulus pair grouping consisted of a fixed stimulus of one type (for example, one of the two flyover recordings) and a variable stimulus of the other type (for example, one of the two sonic booms). The stimulus pair groupings are listed in Table 1. Results from experiment 1 provided the basis for selection of the values of the fixed stimulus and the range of the variable stimulus. The variable stimulus within a stimulus pair grouping was presented at four levels, resulting in 16 stimulus pairs. The order in which each stimulus within a pair was presented was also interchanged, adding an additional 16 stimulus pairs for a total stimuli set of 32 pairs. These were presented in four sessions of eight stimulus pairs each.

Test Procedure

In experiments 1 and 2 subjects were delivered to the laboratory in two groups of four, with one group in the morning and one group in the afternoon. Upon arrival at the laboratory, each group was briefed on the overall purpose of the experiment and system safety features (Appendix C). They were then briefed on their rights as test subjects and asked to sign a voluntary consent form (Appendix D). The subjects were then given the specific instructions related to the test procedure to be followed and in the use of the scaling method (11-point numerical scale for experiments 1 and 3, paired comparisons for experiment 2). At this point the subjects were taken individually from the waiting room to the sonic boom simulator. At the simulator the scaling method was reviewed and the subjects listened to several test stimuli, played with the simulator door open, in order to become familiar with the type of sounds he/she would be asked to evaluate. The subject was then given a practice scoring sheet and seated in the simulator with the door closed. A practice session was then conducted in which the subject rated a set of stimuli similar the those used in the actual test sessions. Upon completion of the practice session, the scoring sheet was collected and any questions answered. The first test session was then conducted.

After all subjects in experiments 1 and 2 completed the first session, they were then cycled through the next session of that particular experiment. No further practice sessions were given. Those participating in experiment 1 completed the the two sessions of that experiment in a single day. Those in experiment 2, however, were required to return one week later to complete the remaining two sessions of that experiment.

In experiment 3 subjects were delivered to the laboratory in groups of eight. The procedure followed was similar to that of experiments 1 and 2 except that two subjects were tested at a time and the test sessions were conducted in the Exterior Effects Room. The subjects were seated at locations for which measured sound levels differed by less than ± 1 dB. As in experiment 1, the subjects in this experiment completed the test in a single day.

Data Analysis

The flyover and boom pressure time histories measured within the simulator and in the EER were computer processed to calculate several noise descriptors for use in determining boom/flyover equivalence. The descriptors were: C-weighted sound exposure level (SELC), A-weighted sound exposure level (SELA), Steven's Mark VII Perceived Level (PL), and Perceived Noise Level (PNL). PL and PNL were determined using methods described in reference 13 and, for the flyovers, represented the peak value over successive 1/2 second time intervals of each event. Sound exposure levels were the energy averaged C-weighted or A-weighted sound levels over an event using a reference duration of 1 second.

DISCUSSION OF RESULTS

Descriptor Considerations

Flyover/boom equivalence was determined for four descriptor-pairs. These were: $SELA_{boom}$ vs $SELA_{fly}$, $SELC_{boom}$ vs $SELC_{fly}$, PL_{boom} vs PL_{fly}, and PNL_{boom} vs PNL_{fly}. The first two descriptor-pairs involved comparisons of weighted sound exposure levels. The third descriptor-pair (PL_{boom},PL_{fly}) was selected on the basis of the demonstrated performance of PL as an estimator of sonic boom loudness. The fourth descriptor-pair (PNL_{boom},PNL_{fly}) was included because of its widespread use as an estimator of annoyance to aircraft subsonic noise and for comparison with the results of reference 8.

Results of Experiments 1 and 2

Experiment 1.- Mean annoyance ratings (averaged over subjects) for each boom and flyover event in experiment 1 are shown in figures 4(a) to 4(d) as a function of noise level for each of the four descriptor-pairs. Also shown are the linear regression lines describing the relationship between annoyance and noise level for each case. The regression lines were determined using the pooled flyover (B747 and A300) and pooled boom (N1 and N3) events respectively. Using the regression lines for a descriptor-pair, the noise levels of the booms and flyovers for equal annoyance were determined for each descriptor. Absolute noise levels were not of primary interest since absolute levels obtained in laboratory situations may not be the same as those obtained in more realistic listening situations. However, the difference between boom and flyover absolute noise levels <u>for equal annoyance</u> may retain validity across listening situations. Therefore boom/flyover subjective equivalence was quantified in terms of this parameter. In the remainder of this paper this parameter, called "noise level difference" (NLD), will always refer to the result obtained by subtracting the flyover noise level from the subjectively equivalent boom noise level for each descriptor-pair.

The NLD's for a descriptor-pair are represented by the spacing between the two regression lines at a given annoyance value. If the two regression lines are parallel (that is, have equal slopes) then the NLD's are independent of annoyance level and can be characterized by a single value. Statistical evaluations of the equality of slopes and offsets of the two regression lines for each descriptor-pair were performed using dummy variable analysis (see ref 14). Unless otherwise noted the probability level selected for statistical significance was 0.01. The dependent variable in each dummy variable analysis was the noise level of a descriptor, the independent variable was mean annoyance, and the dummy variable was type of sound (that is, aircraft flyover or sonic boom). Interaction terms were included to determine whether the slopes of the regression lines differed.

Results of the dummy variable analyses indicated that the slopes of the regressions lines for each descriptor-pair of figure

4 did not differ significantly. Thus the NLD's were independent of the magnitude of annoyance and could be represented by single values. These values, listed in the second column of Table 2, are strongly descriptor dependent. Since these results were based upon pooled boom and pooled flyover responses, they do not reveal possible effects due to the noise characteristics of the particular booms and flyovers being compared. This issue is addressed in the section (see below) which discusses Experiment 2 results.

For the PNL descriptor-pair the NLD was 11.5 dB which agreed well with the 12 dB difference observed in reference 8. For all descriptor-pairs except SELA boom noise levels exceeded flyover noise levels when judged equally annoying. This change in polarity for the SELA descriptor-pair was likely due to the A-weighting frequency characteristics which greatly minimized the influence of the very low frequency boom components.

Experiment 2.- Use of the paired comparison method in experiment 2 required a different procedure for determining subjective equality and NLD. In particular, the design of experiment 2 was such that NLD's could only be obtained for the individual stimulus pair groups. (It was not possible to pool the flyover and boom data as done in experiment 1.) The procedure used is described below.

From the paired comparison judgments, the proportion of subjects who rated each variable stimulus as more annoying than the fixed stimulus was determined. These proportions are displayed in figures 5(a) to 5(d) for each stimulus pair grouping. Note that each figure presents results for all four descriptors

(PL,PNL,SELC,SELA). Also the levels of the standard stimuli for each descriptor-pair are indicated in the legend of each figure. The two cases in which the fixed stimuli were flyovers are displayed in figures 5(a) and 5(b) and the two cases where the fixed stimuli were sonic booms are shown in figures 5(c) and 5(d).

The point of subjective equality for the variable stimulus within a stimulus pair group was the level of the variable stimulus corresponding to a proportion more annoying of 0.5. Once determined, the difference between the level of the variable stimulus and that of the fixed stimulus was obtained with the subtrahend always being the flyover level. The set of NLD's obtained by applying this procedure to each descriptor-pair within each stimulus group is summarized in Table 3 under the columns labeled Exp 2. Inspection of these columns in Table 3 shows that the NLD's obtained using paired comparisons varied significantly across stimulus groups. This indicates that subjective equality between sonic booms and aircraft flyover noise depended upon the particular boom and flyover being compared.

To compare NLD's obtained using paired comparison scaling with those obtained using the continuous 11-point numerical scale, additional dummy variable analyses of experiment 1 data were required. These additional analyses were performed using subgroups containing the same stimulus pairs as those of experiment 2. Results of the reanalysis of the continuous numerical scale data of experiment 2 are also listed in Table 3 under the columns labeled Exp 1. As indicated, the magnitudes of the NLD's derived from the numerical scale data agreed reasonably well with the paired comparison results. In addition the dependence of subjective equality upon the particular sounds being compared was very similar to that observed using paired comparisons.

Also listed in Table 3 are the arithmetic averages (over the four stimulus pairs) of the NLD's for each descriptor-pair and scaling method. These averages are an overall measure of how well boom/flyover equivalence agreed between the two experiments. Examination of Table 3 indicates that the averaged NLD's of experiments 1 and 2 agreed within 1.9 dB, with the best agreement occuring for the two sound exposure level descriptors. This good agreement across studies that used independent scaling methods provided increased confidence in the subjective equality results.

Results of Experiment 3

Experiment 3 results are presented in figures 6(a) to 6(d). Dummy variable analyses of these data showed that all regression line pairs were parallel, again enabling the NLD's to be represented by single values. These values are listed in column 3 of Table 2. Comparison of column 2 (sonic boom simulator results) with column 3 (EER results) indicates that, except for the PNL descriptor-pair, the NLD's obtained in the EER differed from those obtained in the booth by about 2.3 to 5.6 dB. Reasons for the good agreement in the one case, and poorer agreement in the remaining three cases, is unclear. One possibility is the presence of biases (psychological, contextual) in each of the two listening situations. If this were true, however, the shifts in subjective annoyance due to the biases would likely have shown up as a consistent trend across all descriptor-pairs. Additional possibilities include variations in waveforms (and hence spectral content) arising from the different experimental situations. For example, the listeners in the EER heard both the original booms and reflections of these booms as well as rattling of fixtures and other objects in the room. Minimal reflections were present within the sonic boom simulator booth. Also, the airtight simulator reproduced frequencies down to 1 Hz whereas the EER sound reproduction system was limited (by the speakers) to frequencies above about 20 Hz. It is interesting to note that the only descriptor-pair (PNL) for which the booth and EER results were in good agreement was the one whose calculation procedure did not account for frequencies below about 50 Hz. This may indicate that the differing results between the two listening situations were due to effects of the low frequency boom components on the calculated descriptors that were not reflected by corresponding changes in subjective evaluations. This further implies that frequencies below 50 Hz should perhaps be ignored in the descriptor calculation procedures.

Comparison to CHABA Working Group 84 Recommendations

CHABA Working Group 84 assessments of available data (1981) on human response to impulsive noise determined that NLD's for SELA (that is, $SELA_{boom}$ - $SELA_{flyover}$) ranged from -11 to -15 dB for equal indoor annoyance. Comparable values obtained in experiments 1 and 3 were -9 dB in the sonic boom simulator and -12 dB in the EER. Thus the present results agreed reasonably well with CHABA assessment of boom/flyover subjective equality when expressed in terms of SELA, especially for the EER booms which were heard in an environment a little more like the indoor booms considered by CHABA.

CHABA also determined that values of SELC for booms and SELA for flyovers that corresponded to equal annoyance collapsed into a single linear function. This function is shown in figure 7. CHABA concluded from this function that SELC for sonic booms was about 5 dB less than SELA for aircraft noise when judged equally annoying.

Regression lines showing the comparable results obtained in the sonic boom simulator and EER are also displayed in figure 7. As indicated in figure 7, the present results did not agree with the CHABA function. SELC of the booms was about 10 to 15 dB more than SELA of the flyovers for equal annoyance. Experiment 1 and 3 results may have differed from those of CHABA because of the current ability to measure the booms and calculate the descriptors with more precision and accuracy. CHABA had to rely on descriptors derived from transformations of peak overpressure. For example, values of $SELC_{boom}$ and $SELA_{boom}$ were not directly obtained by CHABA but were determined by empirical conversion of peak overpressures to each of the respective descriptors.

CONCLUDING REMARKS

Subjective equivalence of aircraft subsonic flyover noise and sonic booms was quantified in terms of the difference between the noise level of a sonic boom and that of a flyover when the two were judged equally annoying. Noise descriptors considered were PL, PNL, SELC, and SELA. The noise level differences were obtained from three experiments, two of which were conducted in a controlled, relatively reflection-free sonic boom simulator and the third in a large, reverberant room. Where possible these differences were compared to boom/flyover equality points obtained by other researchers. Significant findings are summarized as follows:

1. Noise level differences corresponding to the point of subjective equality depended upon the noise descriptor used and the particular sounds being compared. This agreed with results of prior studies and reflects differences between source characteristics, listening environments, and the descriptor calculation procedures.
2. Noise level differences for PNL and SELA compared favorably with similar results and recommendations from prior studies.
3. Subjective equality results obtained in the sonic boom simulator using two independent scaling methods agreed very well. This provided increased confidence in the validity of the obtained results.
4. Except for the PNL noise descriptor, noise level differences obtained in the Exterior Effects Room did not agree with those obtained in the sonic boom simulator. Possible reasons include differences in boom spectral content within the two listening situations, effects due to reflections and rattle in the EER, and descriptor calculation procedures.

5. The good agreement (across studies) of the noise level differences obtained for PNL, and the good performance of PNL in both listening situations, implies that PNL may be the better descriptor for use in assessing boom/flyover equality.
6. Comparison of the present results with CHABA assessments of boom/flyover subjective equality indicated reasonably good agreement when the two types of noise were compared on the basis of SELA. However, the present results did not agree with CHABA when SELC for booms was compared to SELA for aircraft subsonic noise. CHABA deduced that SELC for booms was about 5 dB less that SELA for aircraft noise when judged equally annoying. The present results found SELC (for booms) exceeded SELA (for flyovers) by about 10 to 15 dB when equally annoying. These differences may be due to current ability to measure the booms and calculate the descriptors with greater accuracy.

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Appendix A - Specific Instructions for Experiments 1 and 3

The experiment in which you are participating will help us to understand the way people respond to various sounds produced by aircraft. We would like you to judge how annoying some of these sounds are.

This test will consist of two 6-minute test sessions. During each session, 10 aircraft sounds will be presented for you to judge. Before each session you will be given a scoring sheet, containing 10 rating scales like the one shown below.

Not Annoying										**Extremely Annoying**
0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

After each sound there will be a few seconds of silence. During this interval please indicate how annoying you judge the sound to be by placing a slash mark along the scale. If you judge a sound to be only slightly annoying, then place you slash mark close to the not annoying end of the scale. Similarly, if you judge a sound to be very annoying, then place your checkmark closer to the extremely annoying end of the scale, that is, near or between a high number near the right end of the scale. A moderately annoying judgment should be marked in the middle portion of the scale. In any case, please make only one slash on each scale. There are no right or wrong answers; we are only interested in your opinion of the sound.

Prior to the first test session, you will be taken to the test facility where you will listen to sounds that are similar to those you will be asked to rate. We will then give you a practice scoring session. Upon completion of the practice session we will collect the practice scoring sheets and answer any questions you may have concerning the test. At this point the first test session will be conducted. You will then return to the waiting room while the other members of your group complete a similar test. You will return to the test facility once more to complete the remaining test session.

Appendix B - Specific Instructions for Experiment 3

The experiment in which you are participating will help us to understand the way people respond to various sounds produced by aircraft. Specifically we would like you to make annoyance judgments of some of these sounds.

This test will consist of eight five-minute test sessions. You will do four sessions during each of your two visits for this test. During each session, 4 pairs of aircraft sounds will be presented for you to judge. For each pair, your task will be to judge which of the two sounds is more annoying. You will be given a rating sheet containing a series of lines like the following:

Circle the more annoying sound

1. First Second

Each pair of sounds will be followed by a few seconds of silence, during which the small red light in front of you will be on. During this interval please indicate which of the two sounds you considered to be most annoying. If the first sound you heard was most annoying, circle First. If the second sound you heard was more annoying, circle Second. Even if you are unsure which was the more annoying please make your best guess and mark one of the two. There are no right or wrong answers; we are only interested in your opinion of the sounds.

Before the first test session each of you will be taken individually to the simulator where you will listen to sounds that are similar to those you will be asked to rate. We will then place you in the simulator and a practice scoring session will be conducted. Upon completion of the practice session we will collect the practice scoring sheets and answer any questions you may have concerning the test. At this point the first two test sessions will be conducted with a short interval between them. You will then return to the waiting while the other members of your group complete a similar test. You will return to the simulator once more to complete the remaining test sessions for today.

Appendix C - General Instructions

You have volunteered to participate in a research program designed to evaluate various sounds that may be produced by certain aircraft. Our purpose is to study people's impressions of these sounds. To do this we have built a simulator which can create sounds similar to those produced by some aircraft. The simulator provides no risk to participants. It meets stringent safety requirements and cannot produce noises which are harmful. It contains safety features which will automatically shut the system down if it does not perform properly.

You will enter the simulator, sit in the chair, and make yourself comfortable. The door will be closed and you will hear a series of sounds. These sounds represent those you could occasionally hear during your routine daily activities. Your task will be to evaluate these sounds using a method that we will explain later. Make yourself as comfortable and relaxed as possible while the test is being conducted. You will at all times be in two-way communication with the test conductor, and you will be monitored by the overhead TV camera. You may terminate the test at any time and for any reason in either of two ways: (1) by voice communication with the test conductor or (2) by exiting the simulator.

Appendix D.- Voluntary Consent Form

VOLUNTARY CONSENT FORM FOR SUBJECTS FOR HUMAN RESPONSE TO AIRCRAFT NOISE AND VIBRATION

I understand the purpose of the research and the technique to be used, including my participation in the research, as explained to me by the Principal Investigator (or qualified designee).

I do voluntarily consent to participate as a subject in the human response to aircraft noise experiment to be conducted by NASA Langley Research Center on

____________________________date

I understand that I may at any time withdraw from the experiment and that I am under no obligation to give reasons for withdrawal or to participate again in experimentation.

I undertake to obey the regulations for the facility and instructions of the Principal Investigator regarding safety, subject only to my right to withdraw declared above.

I affirm that, to my knowledge, my state of health has not changed since the time at which I completed and signed the medical report form required for my participation as a test subject.

____
Print Subject’s Name

____
Signature of Subject

Table 1.- Stimulus Pair Groupings

Grouping	Fixed Stimulus	Variable Stimulus
1	B-747	N1*
2	A-300	N3
3	N1	A-300
4	N3	B-747

* Note: N1 and N3 represent symmetrical N-waves with rise times of 1 and 3 milliseconds, respectively.

Table 2.- Noise Level Differences for Pooled Boom and Pooled Flyover Data of Experiments 1 and 3 for Each Descriptor-Pair.

Descriptor-Pair	Experiment 1 (Sonic Boom Simulator)	Experiment 3 (Exterior Effect Room)
PL_{boom}, PL_{fly}	12.9	10.6
PNL_{boom}, PNL_{fly}	11.5	11.7
$SELC_{boom}$, $SELC_{fly}$	4.3	-1.3
$SELA_{boom}$, $SELA_{fly}$	-8.7	-11.6

Table 3.- Noise Level Differences for Experiments 1 and 2 for Each Stimulus Pair Group and Descriptor-Pair.

Stimulus Pair STD	Stimulus Pair VAR	Descriptor Pair PL Exp 1	PL Exp 2	PNL Exp 1	PNL Exp 2	SELC Exp 1	SELC Exp 2	SELA Exp 1	SELA Exp 2
B-747	N1	14.3	17.5	13.0	15.9	3.6	5.5	-8.4	-6.4
A-300	N3	13.0	14.4	11.6	12.5	6.8	6.9	-8.1	-8.3
N1	A-300	10.0	11.0	8.8	9.9	0.9	1.1	-10.1	-10.0
N3	B-747	17.4	19.6	15.8	17.2	9.5	10.1	-6.3	-6.0
Average		13.7	15.6	12.3	13.9	5.2	5.9	-8.2	-7.7

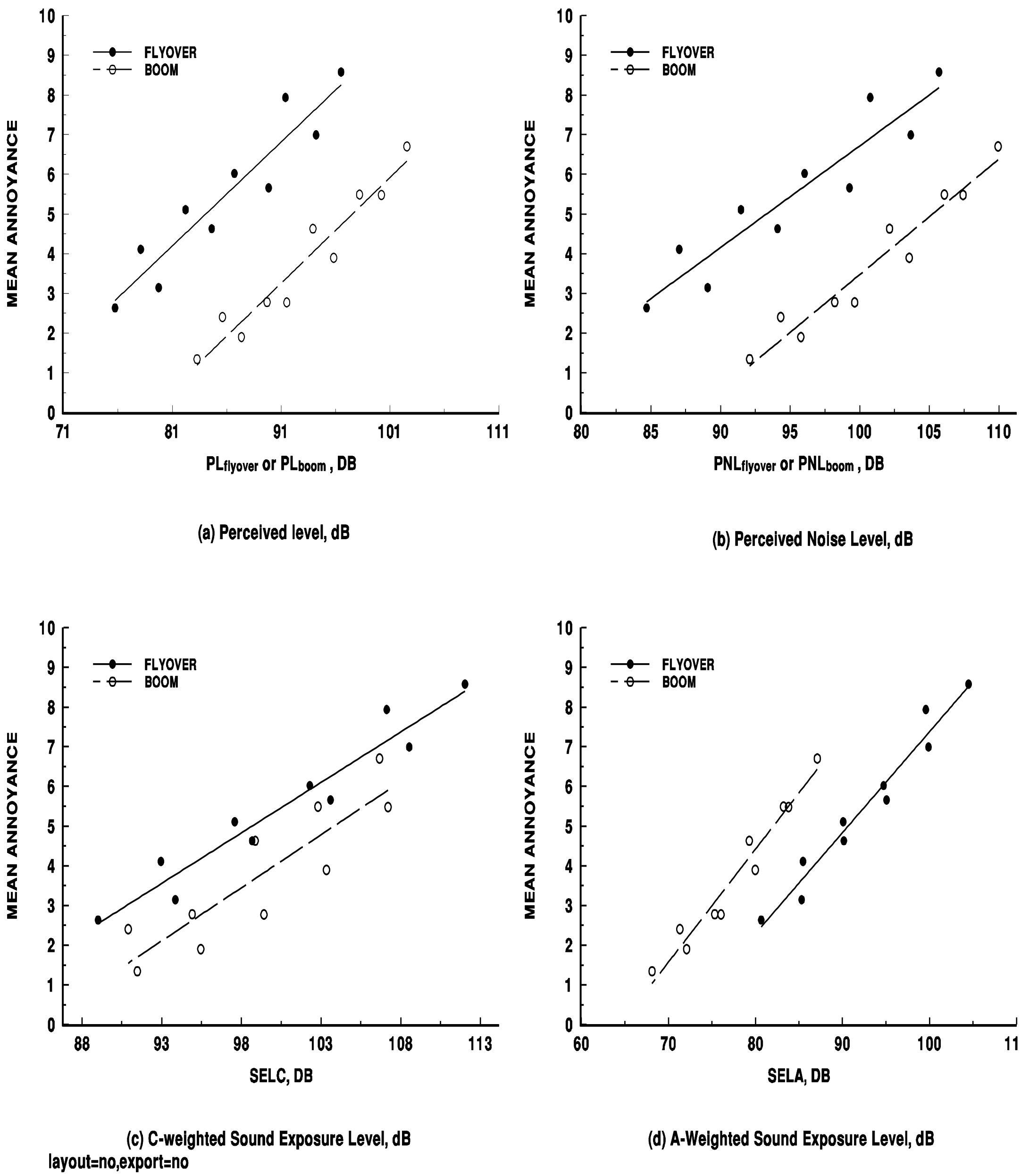

Figure 4.- Mean annoyance scores for the booms and flyovers of Experiment 1 (Sonic Boom Simulator) as a function of noise level for each descriptor pair.

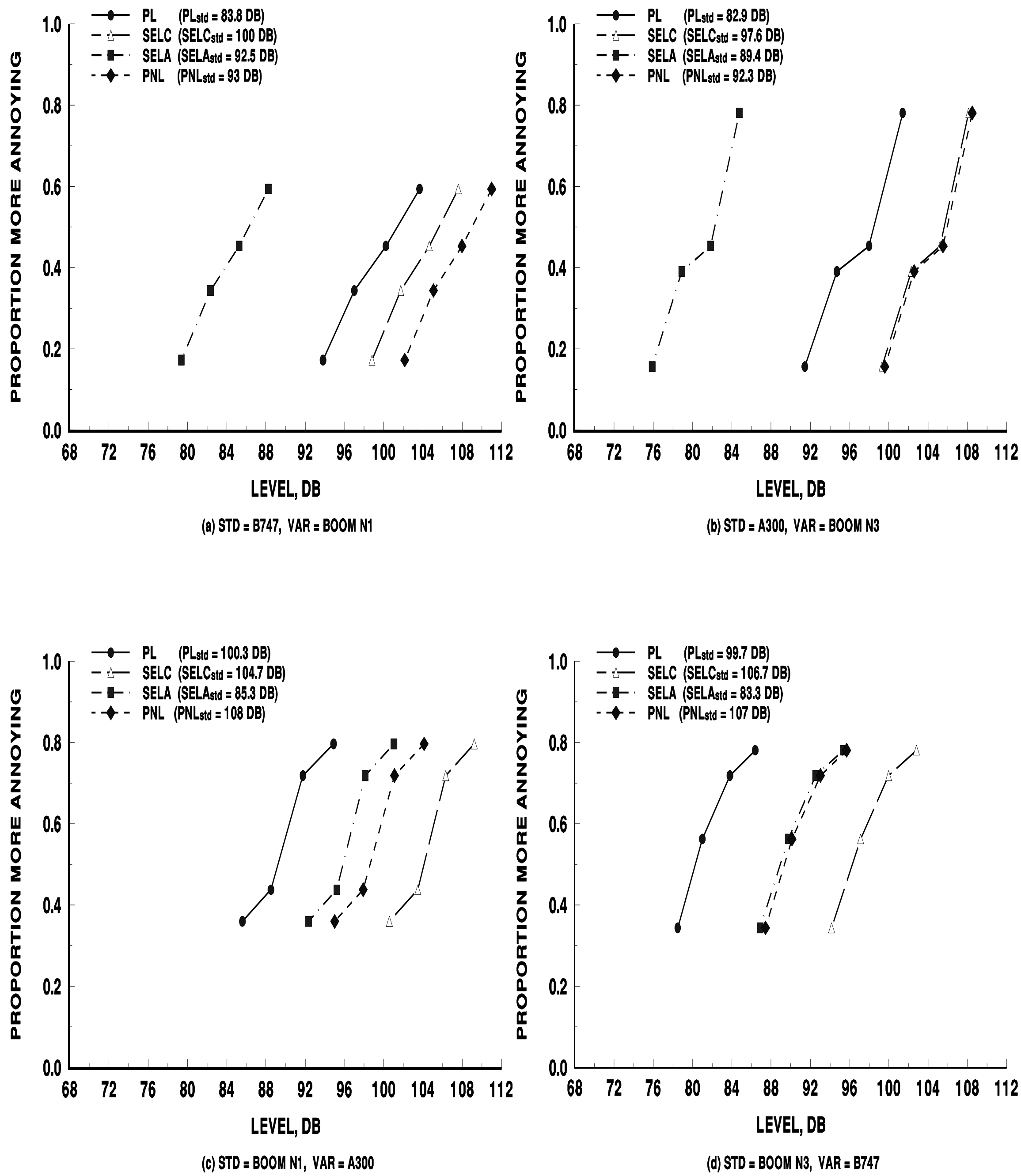

Figure 5.- Proportion of responses indicating variable stimulus to be more annoying than the standard stimulus for each stimulus pair grouping.

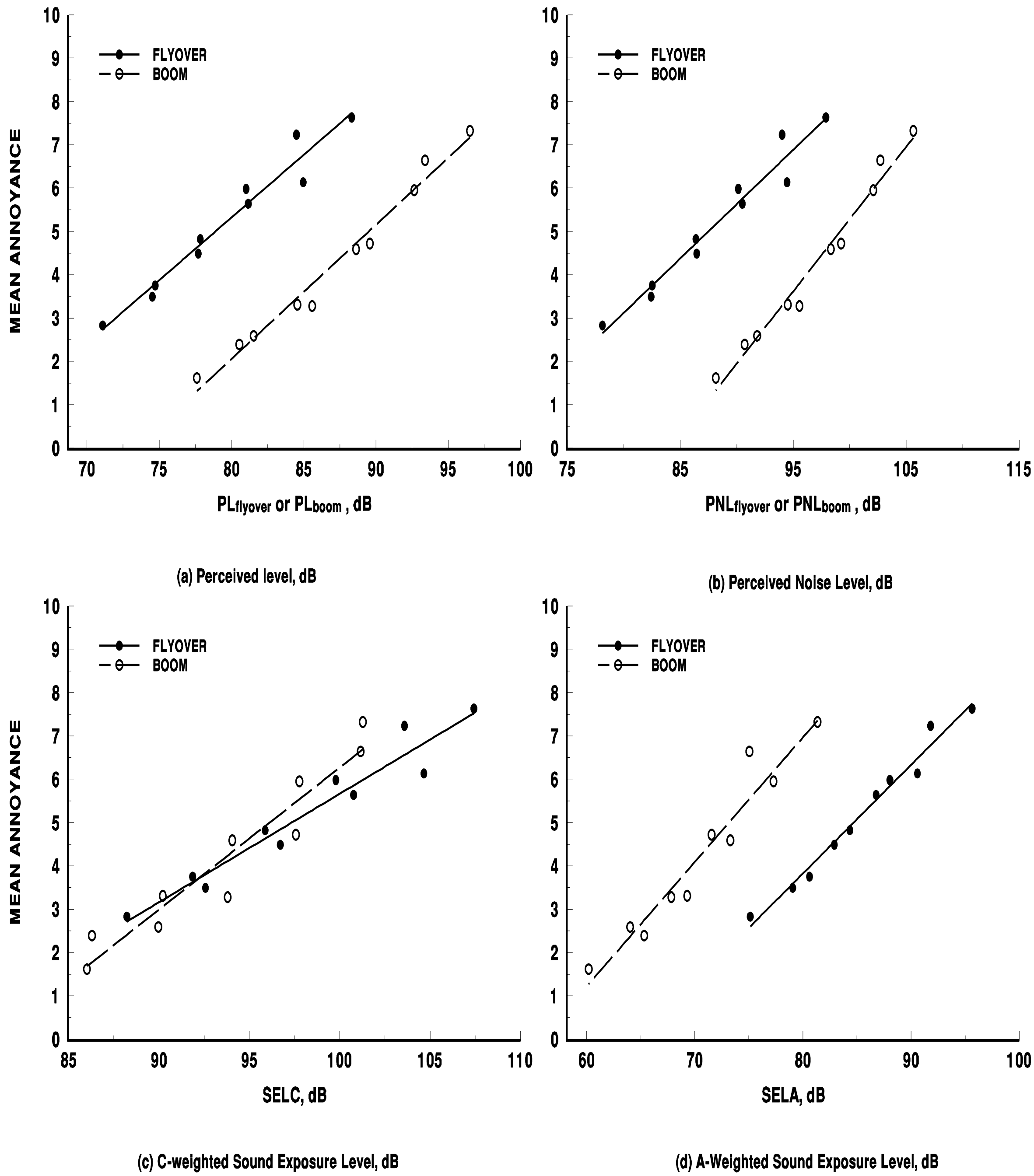

Figure 6.- Mean annoyance scores for the booms and flyovers of Experiment 3 (Exterior Effects Room) as a function of noise level for each descriptor-pair.

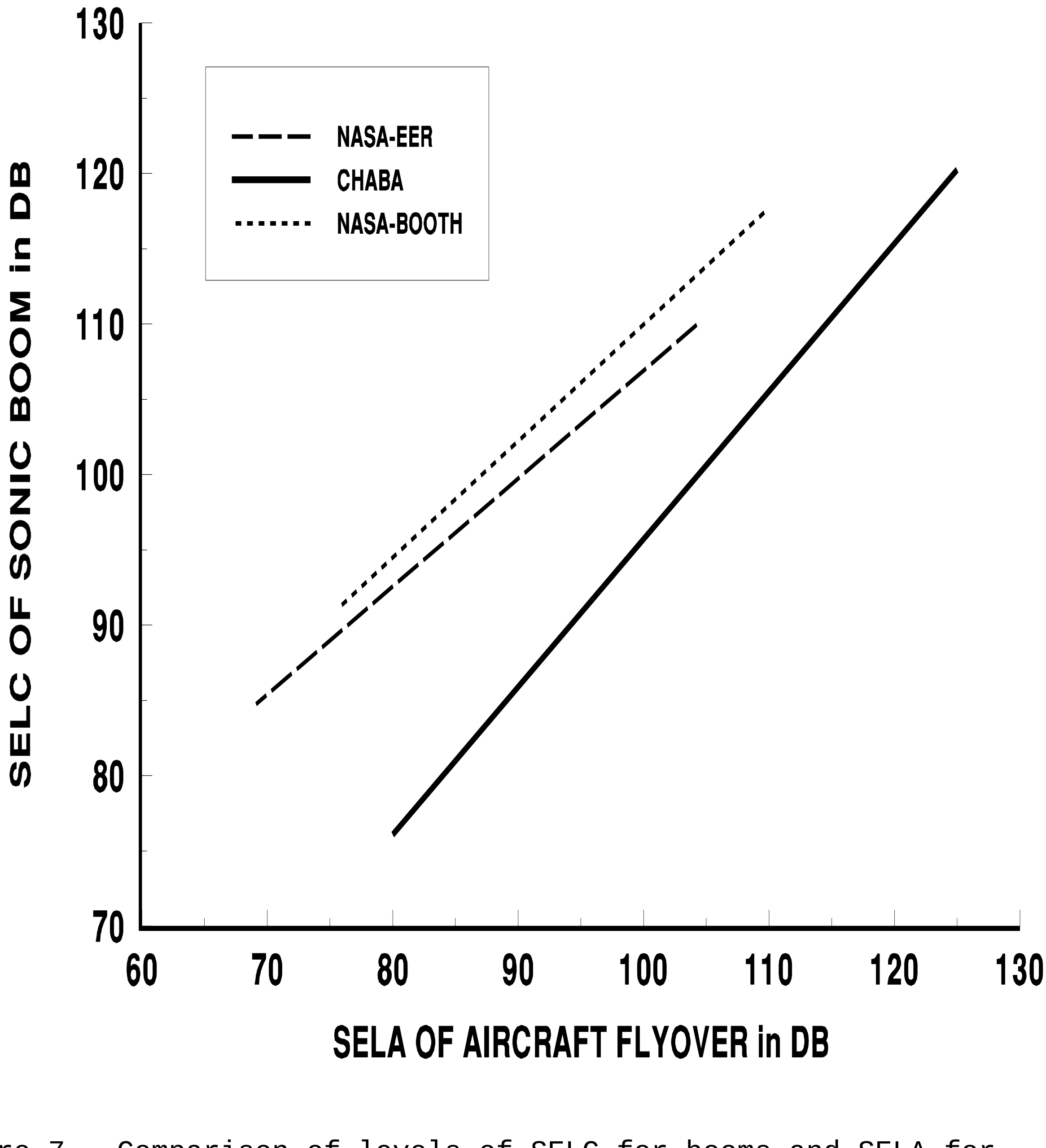

Figure 7.- Comparison of levels of SELC for booms and SELA for flyovers that correspond to equal annoyance as based upon CHABA assessment and the results of experiments 1,2, and 3.